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TEKSCOPE

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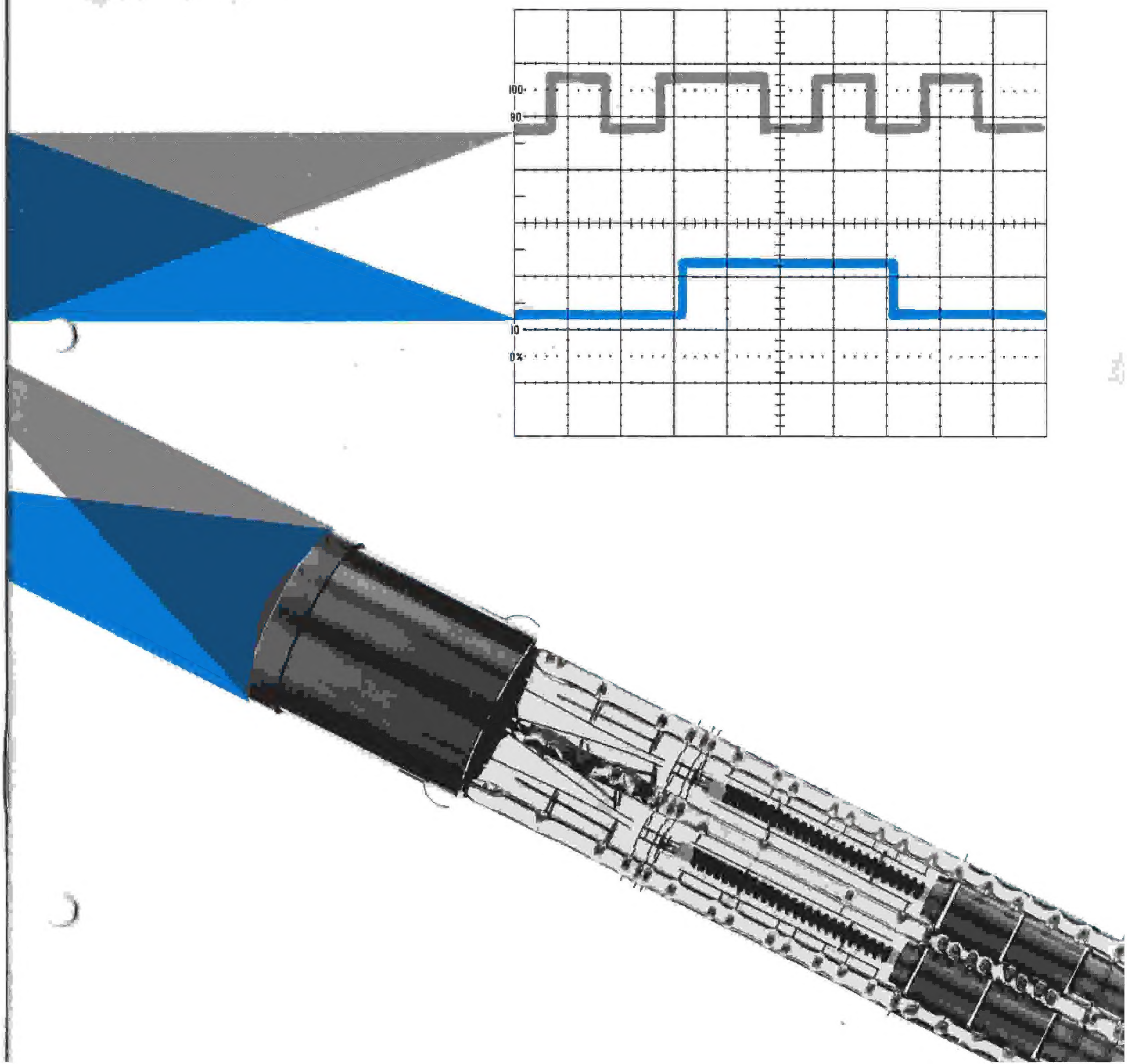

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TEKSCOPE

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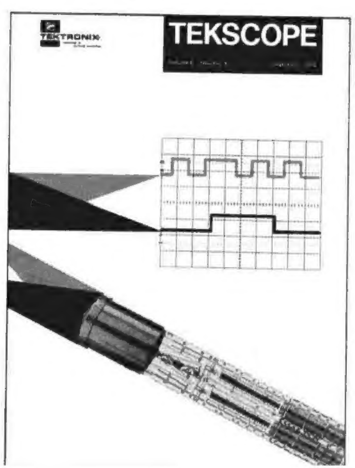
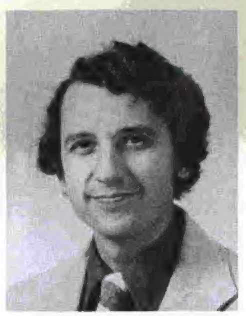
Contents

Cover: Some of the unique design incorporated in the dual-beam crt used in the 7844 is evident in this photo of the crt gun structure. The crt is considerably smaller than previous dual-gun tubes and both beams write over the full screen area.



A 400-MHz dual-beam oscilloscope



Murlan Kaufman

One of the things an oscilloscope does best is show us tiny bits of history, events that occur in microseconds, nanoseconds or picoseconds. But the vast majority of shows pictured on oscilloscopes are re-runs — events that are just like many others that occurred just moments before. It means you can take a look at the crt screen and see a steady display because similar events are happening so quickly and repeatedly that persistence of vision lets you think only one graph is displayed.

Oscilloscopes also let us conveniently *compare* bits of history. Waveform comparisons are often just as important as waveform measurements. There is no better way to judge the similarities and differences between two waveforms than to place them side by side. Scope users choose dual-channel scopes and plug-ins over single-channel varieties by a great margin, simply to be able to compare two signals.

A one-shot event may be an event that is unlike any that has ever happened before or will happen again. Capturing such a unique bit of history can be pretty important and require the help of a fast-writing, wideband oscilloscope plus a high speed camera. You can have a special problem, though, when you want to capture *and* compare two simultaneous, or nearly simultaneous, events. Capturing two such events is either done with two separate oscilloscopes and cameras, or with one camera and one dual-beam oscilloscope. A dual-trace scope operated in the chopped mode can only do a good job if the event lasts longer than about 100 μsec.

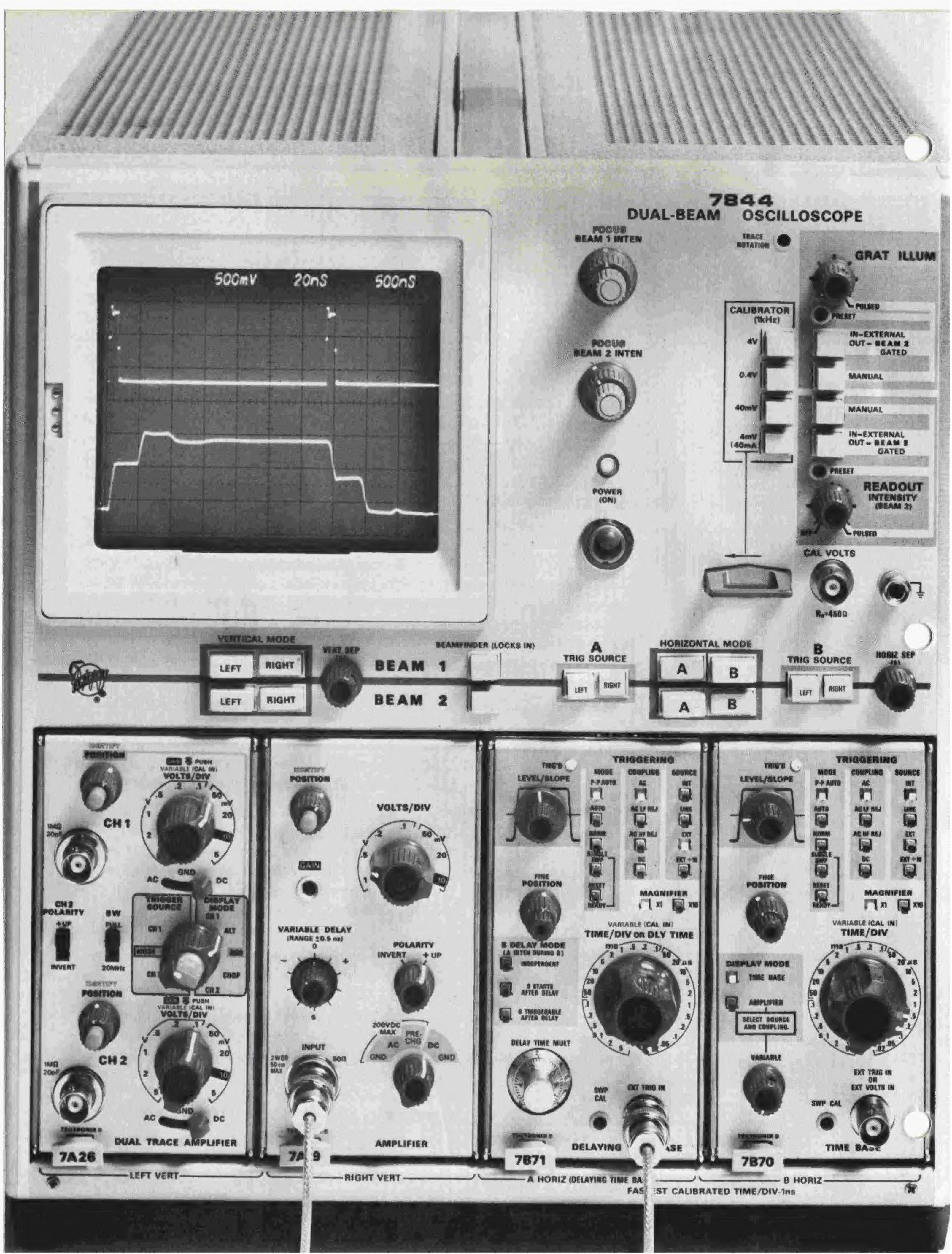
When you capture two one-shot events using a dual-trace or dual-beam scope, comparing the two waveforms is no problem because they both appear on one photograph. Critical comparison of two signals on separate photographs is more difficult. And it is more difficult to successfully take pictures of two simultaneously triggered, and equally delayed, sweeps on separate scopes.

A giant step in bandwidth

For the last nine years the fastest dual-beam oscilloscope available has been the TEKTRONIX 556, a 50-MHz instrument. The new 7844 Dual-Beam scope from Tektronix will replace it. The 7844 has eight times the bandwidth, 400 MHz, and bandwidth is extended to 1 GHz using one or two 7A21N plug-ins with direct-access to the vertical deflection plates.

Less weight, power, rack space

The 7844, and its rackmountable counterpart the R7844, are very similar in performance to two 500-MHz TEKTRONIX 7904 scopes placed in one cabinet and made to share the same crt screen. The volume of the 7844 is, however, the same as that of *one* 7904. Both are four-hole mainframes. The front-panel height of the R7844 is only 7 inches, one-half that of the rackmountable R556. You can put two R7844's where one R556 was used before. The 7844 weighs only 36 pounds, less than half that of the 556, and power required is 235 watts, less than one-third that of the 556. Because the 7844 has a DC fan it will operate from a power line having a frequency from 48 Hz to 440 Hz.


7844
DUAL-BEAM OSCILLOSCOPE
500mV 20nS 500nS
FOCUS
BEAM 1 INTEN
FOCUS
BEAM 2 INTEN
POWER
(ON)
TRACE ROTATION
GRAT ILLUM
PULSED
PRESET
CALIBRATOR
(1kHz)
4V
0.4V
40mV
4mV
(40mA)
IN–EXTERNAL
OUT– BEAM 2
GATED
MANUAL
MANUAL
IN–EXTERNAL
OUT– BEAM 2
GATED
PRESET
READOUT
INTENSITY
(BEAM 2)
PULSED
CAL VOLTS
VERTICAL MODE
LEFT
RIGHT
LEFT
RIGHT
VERT SEP
BEAM 1
BEAM 2
BEAMFINDER (LOCKS IN)
A
TRIG SOURCE
LEFT
RIGHT
HORIZONTAL MODE
A
B
A
B
B
TRIG SOURCE
LEFT
RIGHT
HORIZ SEP
POSITION
VOLTS/DIV
CH 1
AC
GND
DC
CH 2
POLARITY
+UP
INVERT
BW
FULL
20MHz
TRIGGER SOURCE
DISPLAY MODE
CH 1
ALT
ADD
CHOP
CH 2
POSITION
VOLTS/DIV
CH 2
AC
GND
DC
DUAL TRACE AMPLIFIER
7A26
POSITION
VOLTS/DIV
GAIN
VARIABLE DELAY
(RANGE ±0.5 ns)
POLARITY
INVERT
+ UP
INPUT
50Ω
200VDC
MAX
PRE-CHG
AC
DC
GND
GND
AMPLIFIER
TRIGGERING
TRIG'D
LEVEL/SLOPE
MODE
COUPLING
SOURCE
P-P AUTO
AUTO
NORM
SINGLE SWP
RESET
READY
AC
AC LF REJ
AC HF REJ
DC
INT
LINE
EXT
EXT ÷10
FINE
POSITION
MAGNIFIER
X1
X10
VARIABLE (CAL IN)
TIME/DIV OR DLY TIME
B DELAY MODE
INDEPENDENT
B STARTS AFTER DELAY
B TRIGGERABLE AFTER DELAY
DELAY TIME MULT
SWP CAL
EXT TRIG IN
7B71
DELAYING
TRIGGERING
TRIG'D
LEVEL/SLOPE
MODE
COUPLING
SOURCE
FINE
POSITION
MAGNIFIER
X1
X10
VARIABLE (CAL IN)
TIME/DIV
DISPLAY MODE
TIME BASE
AMPLIFIER
SELECT SOURCE AND COUPLING.
VARIABLE
EXT TRIG IN
OR
EXT VOLTS IN
SWP CAL
7B70
TIME BASE
LEFT VERT
RIGHT VERT
A HORIZ (DELAYING TIME BASE)
B HORIZ
FASTEST CALIBRATED TIME/DIV-1ns

Single-shot photos simplified

The 7844 brings crt readout to dual-beam scopes for the first time. Since the 7844 will be used with a camera frequently, the alpha-numeric crt readout characters are especially valuable. They document the sweep speed and vertical deflection factor automatically for each beam displayed.

A pulsed mode of illuminating both the readout characters and the edge-lit crt internal graticule lines greatly simplifies the job of consistently taking good one-shot photographs. Although the pulsed graticule mode is available as an extra-cost option on one other TEKTRONIX single-beam scope (R7903), the feature is standard in the 7844.

In the pulsed mode the graticule illumination lamps are turned off and the crt readout character generators deactivated until a pushbutton is pushed, an external switch is closed, or the awaited one-shot sweep occurs. When controlled by the sweep, each character is generated and displayed once in a rapid sequence immediately following the sweep. Then the graticule lamps are pulsed once briefly.

Front-panel screwdriver adjustments are provided to set the brightness of the readout characters and internal graticule lines to match the camera film speed and f-stop. Each photograph will then have correctly exposed readout characters and graticule lines independent of the time the camera shutter remains open.

Front-panel pushbuttons permit manually pulsing the graticule lines or readout, independently. This is helpful in setting the screwdriver adjustments and getting optimum exposure of the graticule and readout when photographing repetitive sweeps.

A rear-panel connector on the 7844 allows remote pulsing of the readout characters and graticule by a switch closure to ground. Two more rear-panel connectors provide power for remote lamps to indicate when each of the one-shot sweeps is armed or has been triggered. Still another connector allows you to reset the one-shot sweeps remotely.

Built-in film fogging

The 7844 is available with an option that provides a new, automatic way to fog the films for enhancing photographic writing speed. The method allows using cameras not compatible with Tektronix Writing Speed Enhancers. No additional equipment is required; everything is built-in. A one-shot crt raster is generated which illuminates the entire crt faceplate by a preset amount, fogging the film through the camera lens. The raster is produced by one beam (Beam 2) as soon as the sweep for that beam ends. In the automatic pulsed mode the crt readout characters are generated and written on the screen by the same beam (Beam 2) as soon as the raster scan is completed.

Room for special plug-ins

Many dual-beam applications require only a single time base for both beams. This leaves room for one of the specialty 7000-Series plug-ins. The 7M13, for example, may be used to generate additional crt readout characters of your choice. You can include date, test number and other such data when you like. In fact, by double exposure, you can insert a 7M13 in place of one of the plug-ins and record its crt characters at a later time. The manually-operated pulsed mode for generating the characters makes this job simple.

The 7D11 Digital Delay plug-in is another example. It can be used to generate long, very precise trigger delay intervals, with the numerical value of delay displayed on the screen. When you wish to photograph two one-shot events that occur after a main trigger signal, the 7D11 can be used to great advantage. The delay interval will be unmistakable when written on the crt.

Full dual-beam sometimes essential

Although two one-shot events are usually displayed using the same sweep speed, with both sweeps starting at the same instant, you sometimes need to compare two one-shot signals that don't occur simultaneously. A full dual-beam scope is usually called for in this application. Two sweep generators are needed, one that sweeps one beam, and another that sweeps the second beam a little later. The 7844 provides maximum flexibility through four pushbuttons that permit sweeping either Beam 1 or Beam 2 from either time base unit without interchanging the units. We call this feature full horizontal crossover.

A similar feature is provided for the vertical channels. The signal from either channel may be displayed on either beam without interchanging vertical plug-ins. We call this full vertical crossover. One of the advantages of vertical crossover is the ability to display the same signal on both beams using only one probe. This eliminates loading the circuit with a second probe. A typical application is measuring both the risetime and duration of a wide, fast-rise pulse. Both sweeps are initiated simultaneously, but one is set to run much slower than the other.

When only one plug-in is used in this way the single vertical position control on that plug-in does not allow the two beams to be separated vertically. The VERT SEP control on the front-panel positions accomplishes this. The HORIZ SEP control lets you position the

beams horizontally to assure that they start together when only one time base unit deflects both beams.

Reliability

The prospect of putting nearly twice as many parts into a 7844 as you will find in a 7904 called for special attention to assuring instrument reliability. Every conceivable reliability factor was scrutinized from the beginning of the project. Components with conservative voltage and power tolerance ratings were selected and air flow from the fan carefully controlled to limit temperature rise in all areas. Exhaustive reliability testing has taken place at all design stages and long term reliability testing is continuing. We are confident that reliability will be exceptionally good.

Serviceability

A help to people who will calibrate and service the 7844 is the fact that many of the circuits are merely duplicates of each other for the two beams. Some circuit boards are identical for both beams. For those already familiar with the popular 7904, learning the 7844 will be very simple since many circuits are similar. The high-efficiency power supply is merely a beefed-up version of that used in the 7904.

State of the art dual-beam crt

Keeping the 7844 small was a design goal from the start. That placed a premium on the space normally required for a dual-beam cathode ray tube. The crt used in the 7844 is much smaller than that used in the 556. Figure 3 shows a comparison. Crt design hurdles were overcome that not only saved space but did some other, more valuable things.

Both beams write full screen

In a dual-beam crt built with two guns, a straight, centerline shot from each gun should converge at the center of the crt screen. How much the gun centerlines miss the center depends on the length of the crt, the angle of convergence, and how far apart you place the cathode-end of each gun. In the 556 crt the upper beam centerline hits the screen one centimeter above center and the lower beam one centimeter below center. Because each beam in the 556 is restricted to a vertical deflection range of 6 centimeters (for optimum bandwidth) only the middle four centimeters of the crt can be shared by both beams. The 4 x 10 centimeter area is called the overlap area. In the 7844 the entire 8 x 10 centimeter screen is shared by both beams, giving twice as much overlap area.

New design yields smaller size

A couple of rather radical design departures made it possible to build the 7844 crt with centerline convergence at center screen. And this was accomplished without making the crt longer or separating the cathodes further than in the 556 crt. In fact the crt was made shorter and the cathodes placed closer together. The first major difference is that the two gun-structures are made parallel and laid side by side instead of placed one on top of the other. This permits the gun structures to be placed closer together, reducing the diameter of the neck of the crt.

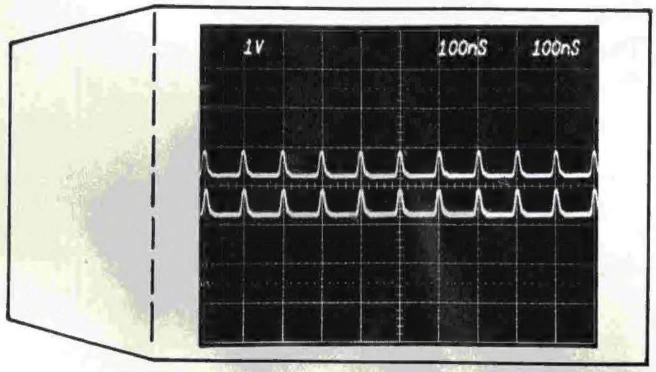


Fig. 1. Excellent crt deflection linearity of both beams shown with 10-MHz time markers.

This kind of construction gives us a left and right beam instead of an upper and lower beam. It also helps keep the two undeflected beams closer together as they emerge from the last pair of deflection plates, reducing the overlap problem. Having a left and right gun instead of an upper and lower gun changes the vertical overlap problem to a horizontal overlap.

The horizontal overlap problem was solved by placing a pair of small auxiliary horizontal deflection plates between the vertical and horizontal pairs of deflection plates of each gun. By applying a dc voltage between each pair of these plates both normally undeflected beams will be aimed at the center of the screen.

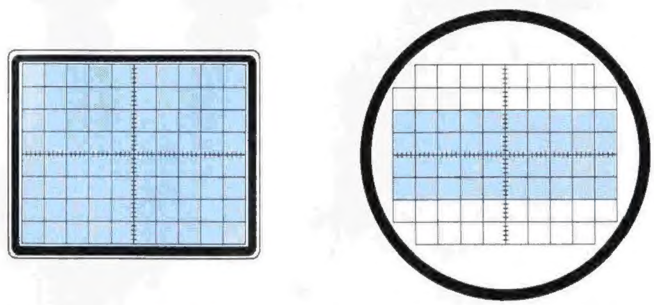


Fig. 2. Each beam in the 556 scans a 6 by 10 cm area providing a 4 by 10 cm overlap area. In the 7844 each beam scans the full 8 by 10 cm area providing twice as much overlap.

One of the reasons dual-beam crt's have traditionally been constructed with one gun above the other is that a deflection linearity problem called keystoning may be easily corrected. Keystoning is an effect which tends to make a trapezoidal pattern instead of a rectangle when a set of raster lines is displayed on the screen. It is caused by a given angle of deflection causing more deflection on one part of the screen than on

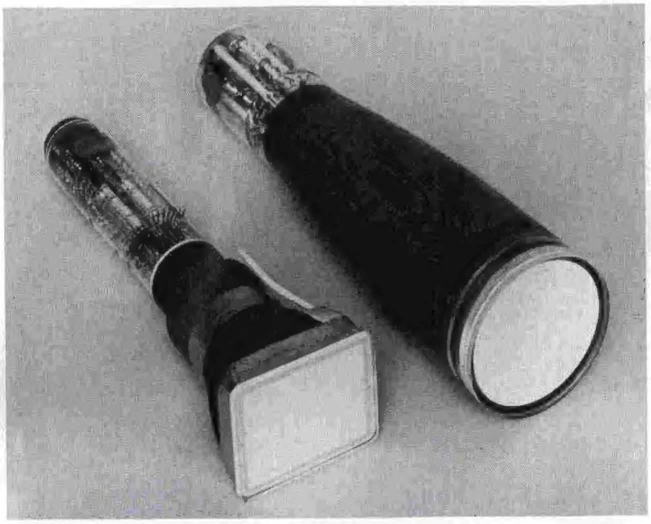


Fig. 3. 7844 crt is shorter than 556 crt and has much less volume.

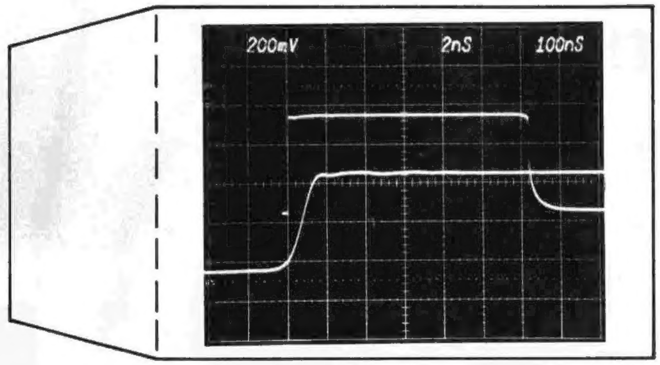


Fig. 4. Two views of the same pulse using two beams. Bottom graph shows risetime and top graph shows duration. Only one input of one vertical plug-in was used. Top sweep was set for 100 ns per division, the bottom for 2 ns per division.

another. For example, the upper gun in a conventional dual-beam crt tends to produce a trapezoid having parallel upper and lower edges with a longer lower edge than upper edge. The effect is corrected for the top gun by mounting the horizontal-deflection plates so the top edges of the plates are closer together than the bottom edges. In effect that equalizes the horizontal-deflection sensitivity across the screen, correcting the keystoning.

When electron guns are placed side by side the inherent tendency to keystone still exists. The difference is that the left and right edges tend to be of different length instead of the top and bottom edges.

This distortion can't be corrected by tilting the deflection plates as with dual-beam crt's having upper and lower guns. Instead it is corrected by applying a dc voltage to an additional plate that lies outside, but adjacent and parallel to, each horizontal-deflection plate. Two additional plates are added for each gun. One edge of these plates extends a little bit further toward the crt screen than the corresponding edge of the adjacent deflection plate, allowing its electric field to extend into the deflection region and correct distortion. Shielding between the two guns increases the horizontal deflection plate capacitance slightly, restricting the top linear speed to 1 ns per division compared to 0.5 ns per division in the 7904.

The crt for the 7844 is not only smaller in diameter than the one used in the 556 but it is shorter. Placing a dome-shaped metal mesh between the deflection plates and the crt screen provides a scan-expansion effect allowing the screen to be brought closer to the deflection plates. The mesh is primarily used to increase crt sensitivity — a necessity for wideband scopes. The penalty is that spot-size is increased and some beam current is intercepted. An accelerating voltage of 24 kV compensates for the beam intercept and yields a writing rate of 1.7 cm per nanosecond (using P11 phosphor, a C51R camera with Type 47 Polaroid® film, and without film fogging.) The 7844 crt is the first dual-gun crt using a dome-shaped scan-expansion mesh.

In summary

The 7844 represents a giant step forward in dual-beam oscilloscope performance. Bandwidth is increased from 50 MHz to 400 MHz and the screen area covered by both beams increased 100% from 4 centimeters to 8 centimeters.

Size, weight and power consumption are substantially reduced. The rack space needed for the R7844 is only 7 inches, half that of its predecessor. A dc fan permits operation from any power line frequency between 48 and 440 Hz.

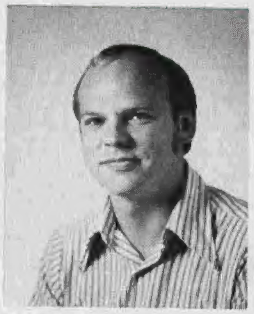
One-shot photography is simplified with a standard feature that provides pulsed graticule illumination and crt readout characters. Built-in film fogging by a one-shot raster scan is available as an option.

Add to these features the unmatched versatility provided by over thirty 7000-Series plug-ins, with four holes to put them in, and you have a dual-beam oscilloscope suited to almost any application.

Acknowledgments

The excellent crt design was done by Conrad Odenthal and Ken Hawken. On the circuit design team, Chuck Scott, Dick Anderson, Keith Taylor and Bob White deserve special recognition. Mechanical designers Mark Anderson and Joal Davis did a top notch job of packaging two scopes in one. My thanks go to these people and to the many others in support groups who were a pleasure to work with and who contributed to the project's success—Murlan Kaufman, Project Mgr.

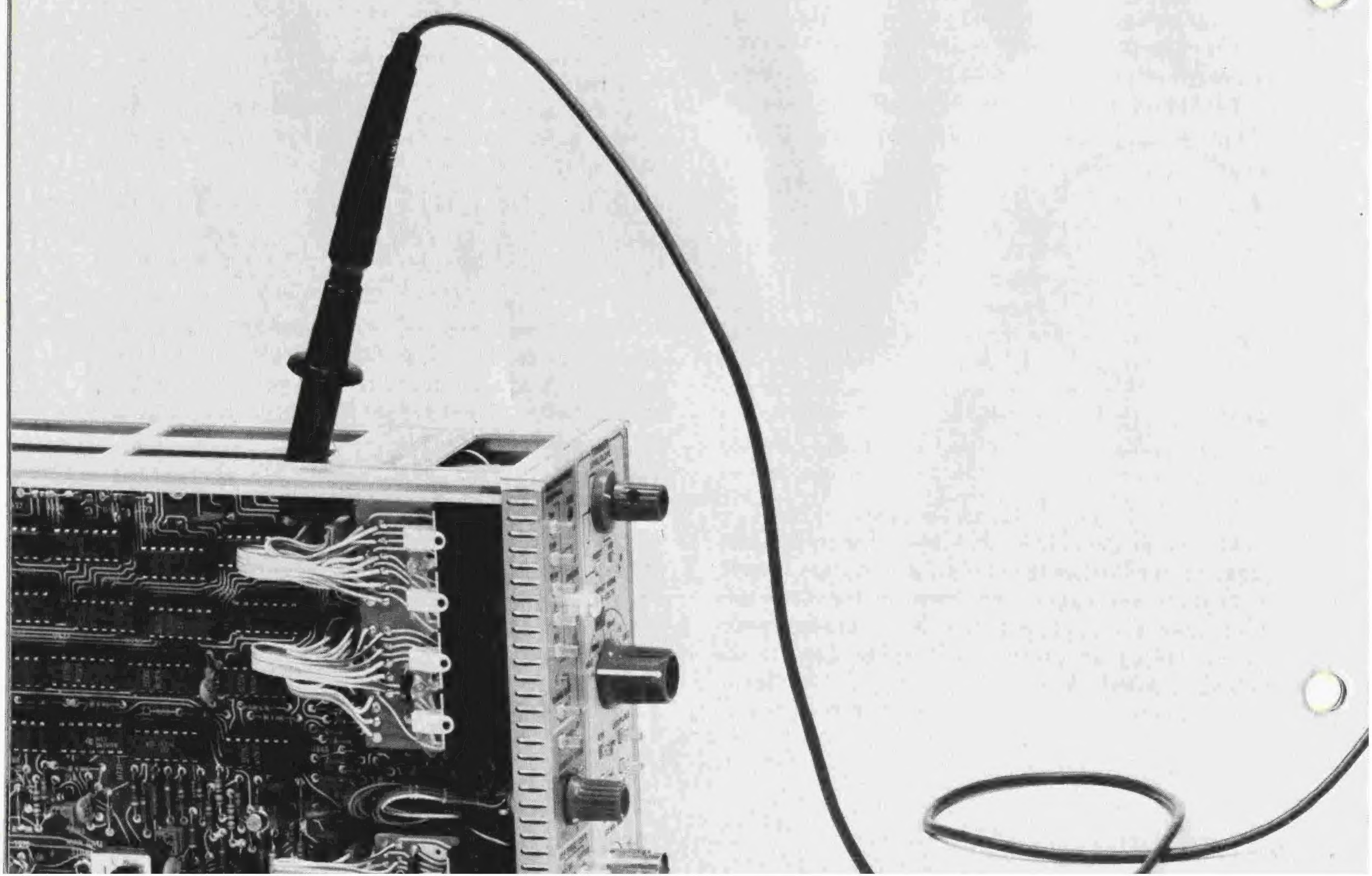
The oscilloscope with the digital multimeter



Dennis Bratz

When asked what tool he considers most important in performing his job the engineer is usually quick to reply, "The oscilloscope". Rated next in importance, undoubtedly, would be the digital multimeter.

For some time these two indispensable tools have been available, as one instrument, in the 7000-Series family of plug-in oscilloscopes. Now the digital multimeter has been added to the portable oscilloscope family. The popular 465 and 475, and the new storage portables, the 464 and 466, offer digital multimeter capabilities including temperature measurement in one compact, easy-to-carry package.



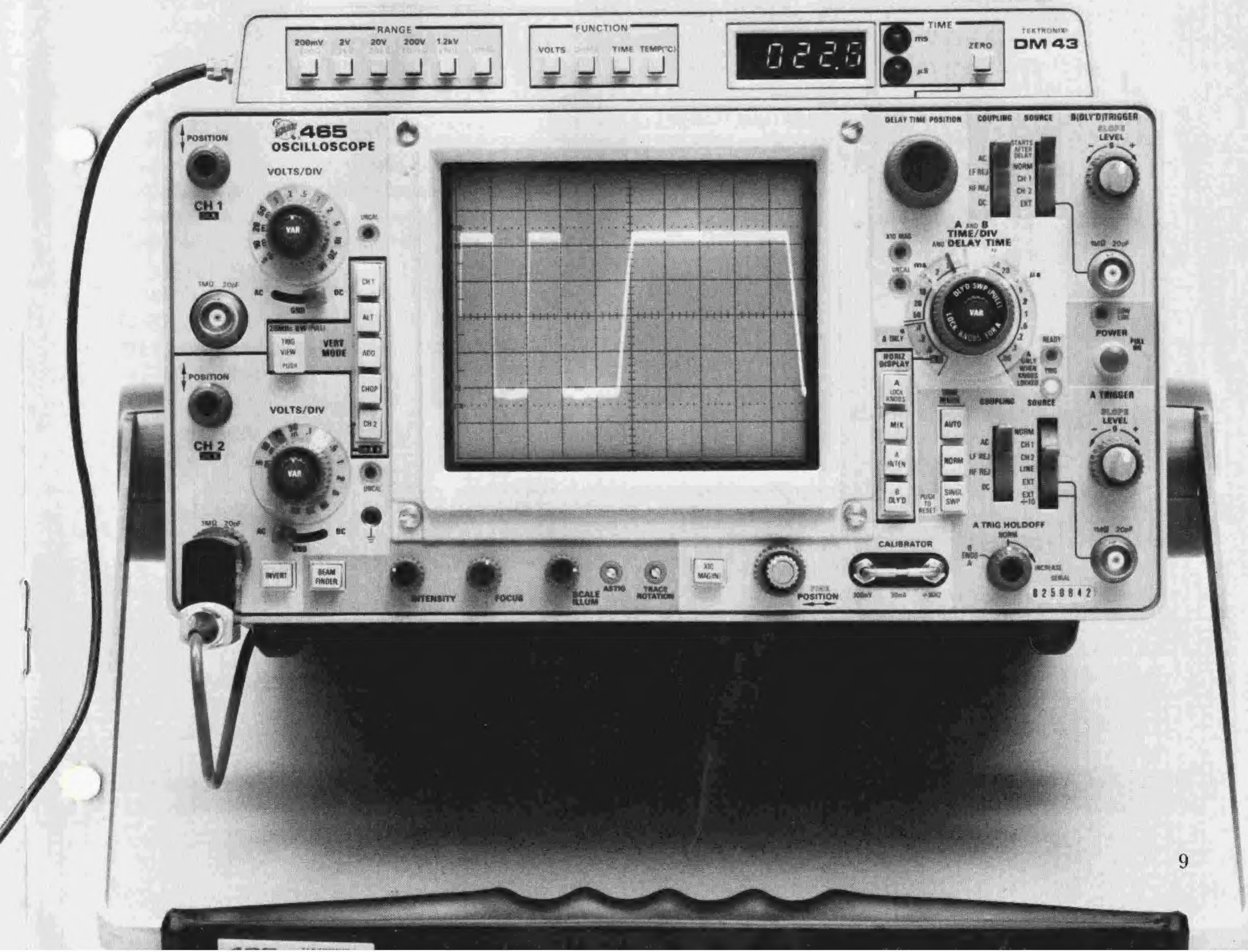
Delaying sweep measurement simplified

One of the factors leading to the addition of a digital multimeter to the portable oscilloscope was a desire to make delaying sweep measurements more easily and reliably. The conventional method of making delay time measurements is to set the delay time multiplier dial to the start of the interval and note the dial reading; then move the dial to the end of the interval and again note the reading. The difference between readings is then computed and multiplied by the sweep time-per-division. While not a complicated procedure, it is relatively time consuming and offers opportunity for error.

In making delaying sweep measurements, the delay time multiplier control selects a dc voltage which is fed into a comparator. The delaying sweep ramp is fed to the other input of the comparator. When the ramp voltage reaches that selected by the delay time multiplier, a trigger signal is generated which starts or arms the delayed sweep. What we are actually doing is selecting a voltage proportional to the point in time on the sweep we wish to measure.

With a digital multimeter as an integral part of the oscilloscope, we can let it compute the time interval for us. Since we are simply measuring two dc levels, all we have to do is tell it when to start measuring and when to stop.

Let's take a moment to study the front-panel controls of the 465 DM43 pictured below. Those of you familiar with the 465 will notice that the DELAY TIME MULTIPLIER with its calibrated dial is replaced by an uncalibrated control called DELAY TIME POSITION. The rest of the scope controls are unchanged.



Shifting our attention to the DM43 you will note two functions not usually found on digital multimeters—time and temperature. It is the time function that is used when making time interval measurements.

Now let's see how easy it is to measure any time interval displayed on the crt using the DM43. With the oscilloscope in either A INTEN or B DELY'D sweep mode, the DELAY TIME POSITION control is used to select the beginning of the interval to be measured. The ZERO button is depressed setting the readout to zero, and the DELAY TIME POSITION is then advanced to the end of the interval. The time interval is read out directly on the 3½-digit LED display. It's that quick and easy.

The temperature function

Making temperature measurements is not new to TEKTRONIX 7000-Series scope users – the 7D13 Digital Multimeter plug-in introduced this feature in 1971. Now the DM43 extends this convenient measurement tool to portable oscilloscope applications.

The temperature probe is a small unit resembling the typical oscilloscope probe in appearance. Temperature is sensed by a silicon npn transistor mounted in the tip of the probe. It is a characteristic of forward biased p-n junctions, that the voltage drop across the junction is temperature dependent. It is this characteristic we use in sensing temperature. The emitter-base voltage of the transistor is the parameter which is measured.

Temperature can be measured from −55°C to +125°C within 2°C, and within 3°C from +125°C to +150°C. If you prefer readings in Fahrenheit, only a minor circuit modification is needed.

The temperature sensor, after mounting in the probe tip, is checked in the laboratory at three temperatures: 0°C, room temperature, and 100°C. This assures that replacement sensors can be calibrated to any temperature probe. Calibration of the temperature probe to the DM43 is checked at two temperatures, using a reference thermometer: 0°C using an ice bath, and room temperature using an equalizing block to provide a uniform temperature environment for the probe and reference thermometer. As with oscilloscope probes, the temperature probe should be calibrated to the DM43 with which it is to be used.

The temperature function is independent of scope operation so you can observe both waveforms and temperature at the same time.

Volts and Ohms

The volts and ohms functions also operate independent of the oscilloscope. Dc voltages from 0 to 1.2 kV can be measured to an accuracy of 0.1%, ±1 count. Resolution is 100µV. Input impedance is 10 MΩ on all ranges, and an internal wire strap can be removed to increase input impedance to approximately 1000 MΩ on the .2 V and 2 V ranges. The common input can be floated up to ±500 volts (dc + peak ac) from chassis.

Resistance can be measured over the range of 0 to 20 MΩ, with an accuracy of 0.75% ±1 count on the 200 Ω, 2 kΩ and 20 MΩ ranges, and within 0.3%, ±1 count on the 20 kΩ, 200 kΩ and 2 MΩ ranges. Resolution is 0.1 Ω.

HOW THE DM43 WORKS

The DM43 consists of three basic sections: (1) the converters for temperature, time and ohms; (2) the digital voltmeter; and (3) the digital readout.

The converters

The temperature converter contains the circuitry for driving the temperature sensor and amplifying the resultant base-emitter voltage for application to the digital voltmeter.

As mentioned previously, temperature is sensed by measuring the base-emitter voltage of an npn transistor mounted in the tip of the temperature probe.

Figure 1 shows the basic circuit used in achieving the change in base-emitter voltage for a given change in collector current. The sensor transistor is connected in the feedback loop of an operational amplifier with the collector at the input, emitter connected to the output, and the base grounded. For a given current input, the output of the operational amplifier forward biases the emitter-base junction of the transistor to the level necessary to maintain the input collector current.

The ratio of the two levels of collector current is set at about 100:1, giving the base-emitter voltage a sensitivity to temperature of slightly less than 0.4 mV/°C.

The signal at the output of the op amp charges a memory capacitor to a dc voltage proportional to temperature. A second op amp sets gain and output dc levels for application to the digital voltmeter.

The time converter measures the voltage at the DELAY TIME POSITION control and proportions that voltage to the 1-2-5 positions of the TIME/DIV control in the oscilloscope (Fig. 2.).

The voltage from the DELAY TIME POSITION control is fed to two buffer amplifiers, one whose output always follows the DELAY TIME POSITION control voltage; the other whose output is held at the

control voltage present when the ZERO button is depressed. A voltage divider between the two outputs provides for equating the output to the 1-2-5 positions of the TIME/DIV switch. The divider gives 2.0 volts output for the twos, 1.0 volt for the ones, and 0.5 volt for the fives positions, respectively.

When the ZERO pushbutton is depressed the outputs of the two amplifiers are at the same voltage. There is no current flowing in the divider so the input to the digital voltmeter is at zero volts. As the HORIZONTAL TIME POSITION setting is changed, the difference in the amplifier outputs appears across the divider and is read by the digital voltmeter and displayed in units of time.

The digital voltmeter

The voltmeter circuit takes the analog signal from one of the input converters and converts it to multiplexed Binary Coded Decimal (BCD) information.

The voltmeter uses dual-slope integration. Two integrated circuits, one analog and the other digital, designed to work as a system, form the heart of the voltmeter. A 20.48 kHz clock provides timing signals to the digital IC. The 20.48 kHz frequency provides a recycle time of about 3.3 measurements per second and gives good 50 Hz and 60 Hz power-line frequency rejection.

Signals from the digital IC tell the analog IC whether to measure or zero, and provide an Up-Down logic signal. The Up-Down logic, in conjunction with the comparison signal from the analog IC, functions to maintain equilibrium in the analog integrator circuits.

The integrator gain is switchable between X1 and X10. When measuring time, gain is switched automatically to keep delay time resolution to a minimum of three places regardless of the time selected. For example, when the count reaches 00.99 ms, the meter will downrange and the reading will shift to 0.999 ms.

The readout

The digital IC also contains the counters and latches. The count comes from the digital IC in BCD format and is fed into a decoder driver. Here the BCD information is converted to 7-segment information to drive the light-emitting diodes in the display.

Five more outputs from the digital IC provide digit selection information for the digit drivers, including the sign function.

A separate set of logic circuits decode the decimal point inputs from the TIME/DIV cam switch in the time mode, the RANGE switch in volts and ohms, and the FUNCTION switch in temperature. They also control the lamps indicating milliseconds or microseconds in the time mode.

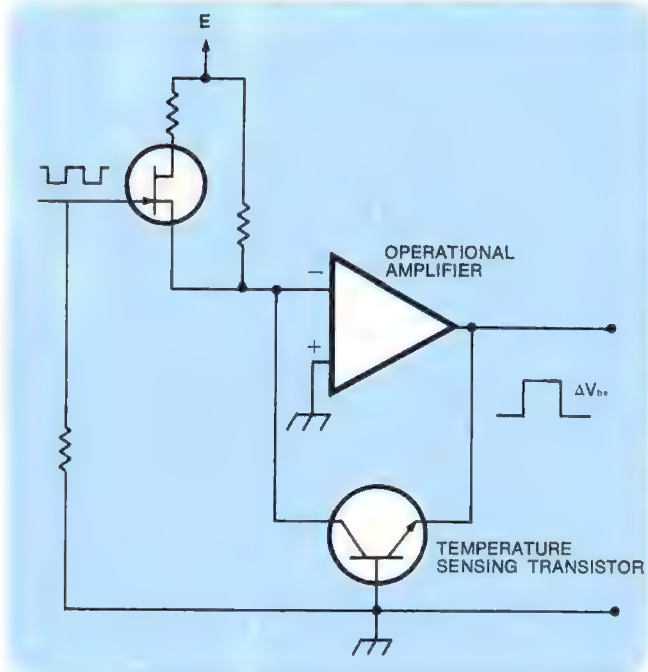


Fig. 1. Simplified block diagram of a portion of temperature converter showing circuit for improving linearity by switching collector current and measuring Δ V_{be} as indicator of temperature.

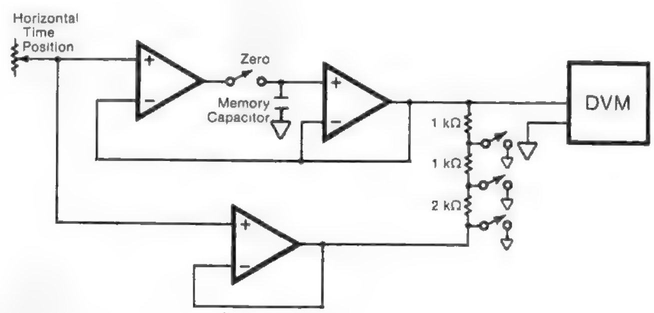


Fig. 2. Simplified block diagram of the time converter circuitry. Voltage divider between op amp outputs codes output voltage to 1-2-5 positions of TIME/DIV switch.

In summary

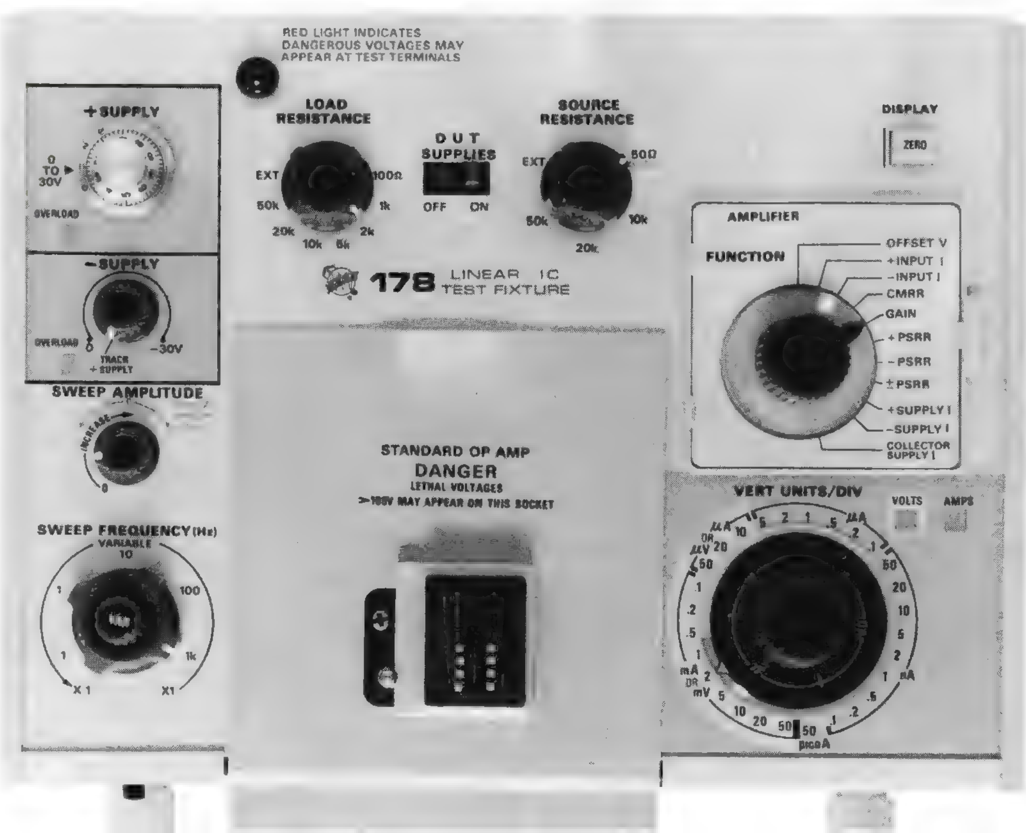
With the addition of a digital voltmeter to the portable oscilloscope, two essential instruments become one. And the measurement capability of each is enhanced by the other. Delay time measurements are made more quickly and with less chance for error. Convenient temperature measurements provide new insight into circuit operation, aiding circuit design and troubleshooting. For those not needing the temperature function, the DM40 provides all the other features of the DM43 at a savings in cost.

Teknique

Op amp bandwidth approximations ....using the 577/178 curve tracer

Engineers usually want to know at least two things about the gain of an op amp, (1) open-loop gain at dc and (2) the frequency at which gain falls off to equal one. The 178 Test Fixture for the 577 Curve Tracer supplies test signals that range from 1 kHz to .01 Hz so op amp transfer curves may be plotted as slowly as necessary to depict dc characteristics such as gain. It is simple to tell when the test signal has a frequency low enough to represent dc characteristics: looping due to phase shift diminishes as frequency is lowered until there is no more loop. There is then no point in lowering the frequency further. Because of the low frequencies used a storage crt is highly recommended.

Few people would suppose that the 178, with its top test-signal frequency limited to 1 kHz, could be used to calculate the unity-gain bandwidth of an op amp, even approximately. Yet there is a simple way it can be used to do this.



The open-loop bandwidth of an op amp is the frequency at which gain has fallen 3 dB below the open-loop dc gain. At twice that frequency (one octave higher) gain will have fallen nearly twice as far (an additional 6 dB). The gain then falls off at a rate very close to 6 dB per octave for at least several octaves in most op amps.

Most monolithic IC Op Amps have such high open-loop dc gain that their open-loop bandwidth is in the low audio or sub-audio frequency range. Therefore, in the mid-audio range the open-loop gain falls off at a rate close to 6 dB per octave. Figure 1 shows a typical curve plotting gain versus frequency. By measuring the gain of an op amp at a known frequency where gain rolls off close to 6 dB per octave, the roll-off can be projected to determine at what frequency gain equals one.

The calculations are very simple for a 6 dB per octave slope because the product of gain and frequency is constant. For example, a gain of 1000 at 900 Hz would tell you to expect a gain of 900 at 1 kHz. It also tells you to expect a gain of 1 near 900 kHz.

The fact that the roll-off rate may increase toward 12 dB per octave starting at some frequency lower than the unity-gain frequency, warns us of a possible source of error, however. In such a case the unity-gain frequency would be a little less than 900 kHz, perhaps 800 kHz.

The gain of most monolithic op amps decreases at close to 6 dB per octave at 1 kHz so the 178 test signal of that frequency is used. The accuracy of the 1 kHz signal is ±5%.

The gain of an op amp at 1 kHz may be easily calculated using the 178. You measure the output voltage-swing caused by a given input voltage-swing, then you divide the first by the second ($E_{out} \div E_{in} = \text{Gain}$). The gain-bandwidth product then is simply gain times 1000.

In the examples shown the 178 test signal (sweep) amplitude was adjusted to cover precisely 5 divisions at 2 mV/div. Then the loop was positioned so the graticule lines were a convenient reference. Finally the peak-to-peak output voltage was read from the horizontal scale and divided by 10 mV.

Summary

Because most op amps have an open-loop bandwidth several octaves below 1 kHz, the slope of the gain curve is typically 6 dB per octave at 1 kHz. If the assumption is made that the slope of the gain curve does not change appreciably until gain has fallen to unity, the unity-gain bandwidth may be easily calculated after measuring the gain at 1 kHz.

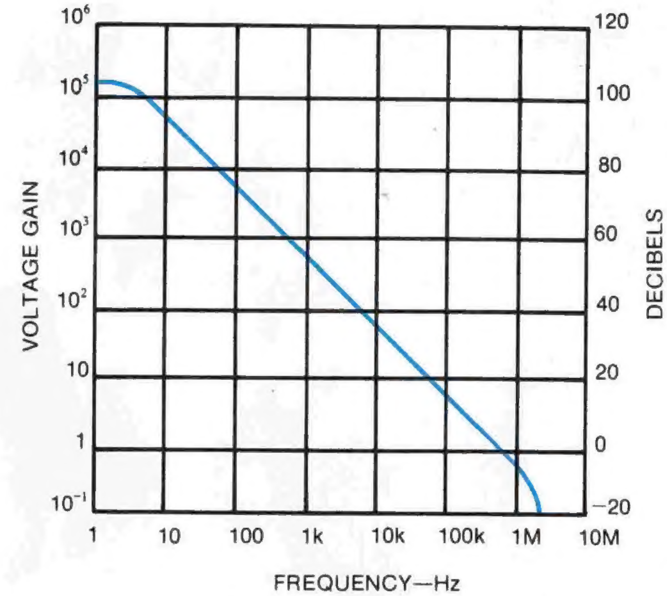


Fig. 1. Typical open-loop frequency response of a 741 op amp. Slope is 6 dB per octave (20 dB per decade) at 1 kHz.

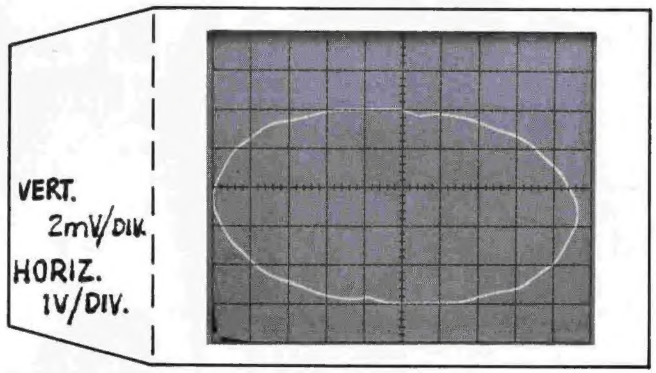


Fig. 2. 741 op amp gain at 1 kHz
$E_{out} = 9.6$ V $E_{in} = .01$ V
Gain $= E_{out}/E_{in} = 9.6/.01 = 960$
Gain-Bandwidth Product = 960 x 1000 = 960,000
Unity-Gain Bandwith = 960 kHz

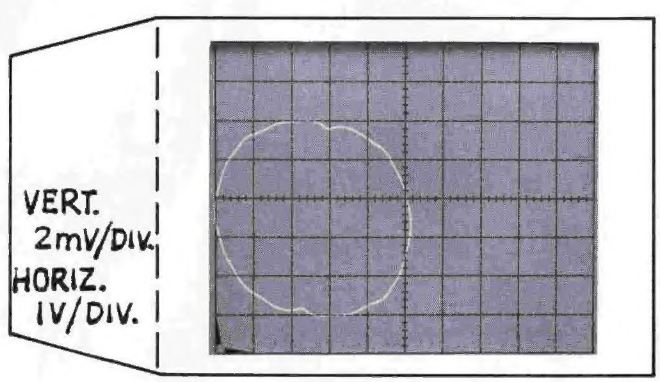
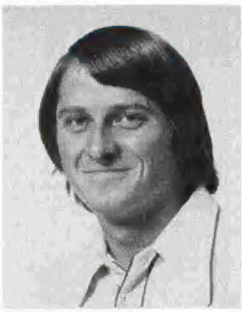


Fig. 3. 301 op amp gain at 1 kHz (using 30 pF external feedback capacitor).
$E_{out} = 5.2$ V $E_{in} = .01$ V
Gain $= E_{out}/E_{in} = 5.2/.01 = 520$
Gain-Bandwidth Product = 520 x 1000 = 520,000
Unity-Gain Bandwith $\approx$ 520 kHz

Servicescope

Troubleshooting the 7B70 and 7B71 time bases



Jim Lawe

Going around in circles may be fine for race drivers but it's not very productive when you don't know where the circle begins or ends. We'd like to take you around the loop that constitutes the time base generator in the 7B70 and 7B71 time bases, and give you some mileposts to check that will make you a winner when there are obstacles in the path, or, in other words, when the sweep won't run. Incidentally, this trip will qualify you to troubleshoot the 7B50 and 7B51 time bases as well.

The block diagram of the 7B71 is shown at right. The blocks screened with light blue are the ones we are concerned with when operating in the INDEPENDENT mode. This is the mode we'll use when troubleshooting the sweep generator circuit.

To set up the 7B71, depress the top three TRIGGERING pushbuttons, set TIME/DIV to 1 ms, and B DELAY MODE to INDEPENDENT. Let's assume that the sweep is not running and the beam is at the left side of the screen. Fire up your test scope, pull out the time base generator schematic in your 7B71 manual and we're ready to start around the loop.

The starting point is TP534. We will give you the conditions that should exist at each milepost and what to check at each point.

Start: TP534
Normal states (0 V to +13 V)
If reading is ≈0 V, pull Q526.
If the sweep runs up to ≈13 V the Miller is alright. If not, check Q532, Q533, Q534, Q537 and associated circuitry. (In the 7B71, Q520 could also load down the sweep.)

Milepost 1: TP436
Normal states (0 V to −3.5 V)
If TP 534 is ≈0 V, TP436 has to be ≈0 V to allow the trigger to fire the sweep through Q360 and Q404. Check to see that Q326 and Q360 are on, and Q328 and CR320 are off.
If TP 436 is ≈3.5 V, Reset Multi Q432, Q436 is not reset. (Q432 off, Q436 on). The Reset Multi must reset so the Sweep Gate Multi can turn off Q526 through Q404 to enable sweep to start.

Milepost 2: TP471
Normal states (−0.7 V to +1.3 V)
TP468 should be at 0 V.
TP471 has to be −0.7 V to turn on Q468 and flip the Reset Multi (Q432 off, Q436 on).
If −0.7 V check Q432, Q436 and associated circuitry.
TP432 should be +5.8 V at this time.
If TP471 is not −0.7 V, proceed to next milepost.

Milepost 3: TP585
Normal states (−8.5 V to +14 V)
Reading should be −8.5 V.
If not, check to see that Q582, Q592 and Q594 are turned off. Check associated circuitry. TP585 should charge negatively and be limited by VR576 and CR576.

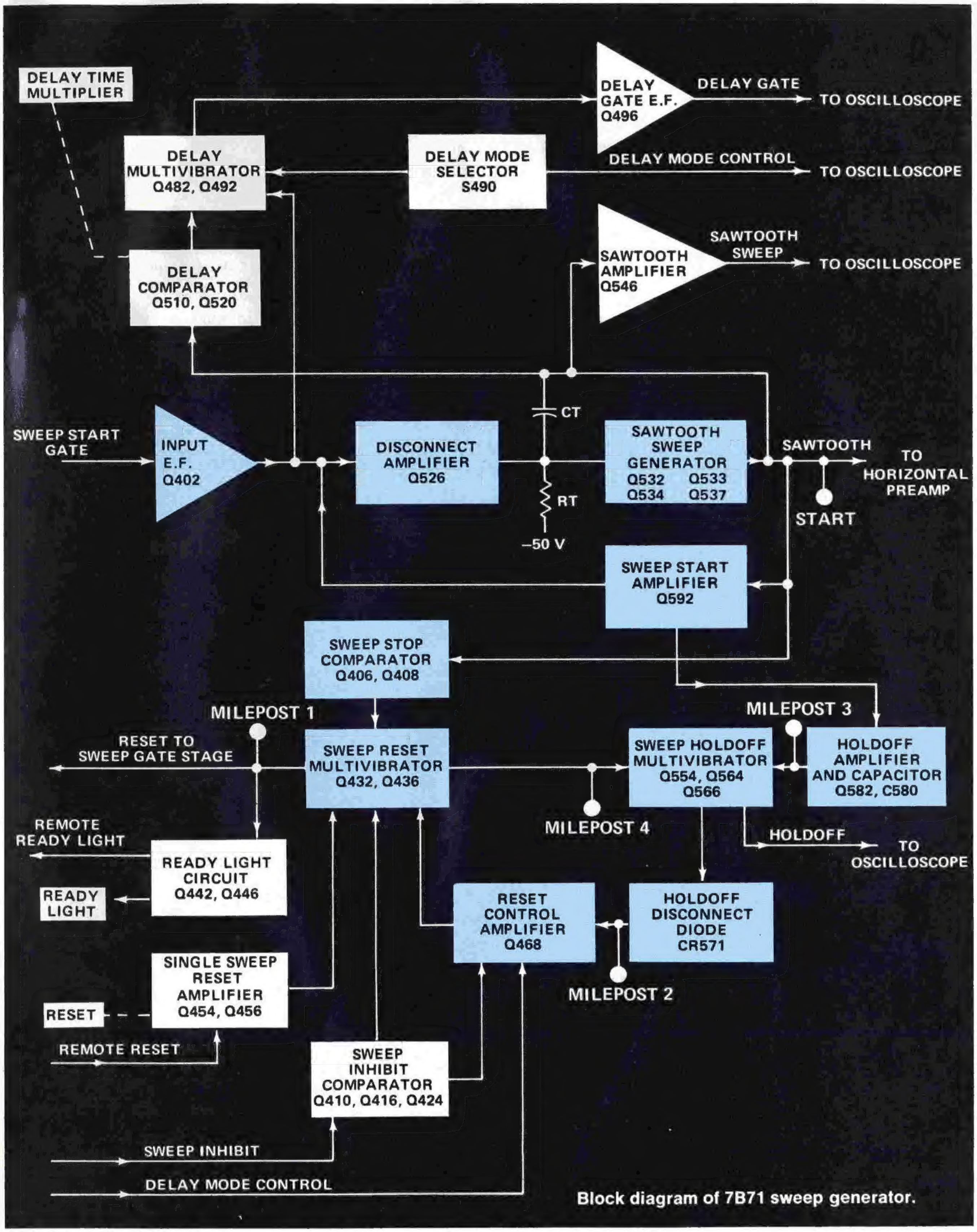
Milepost 4: TP554
Normal states (−5 V to −6.8 V)
If TP585 is −8.5 V, TP554 should be −6.8 V.
If not, check CR575 and CR574.

This completes the basic "loop" for sweep operation. Let's go back to Milepost 1, TP436, and see what happens when we achieve 0 V at that point. Through CR320, Q326 is turned on and Q328 off. VR358 switches to its high state. If Q360 receives a trigger, the Sweep Gate Multi flips and a negative gate is coupled through Q404 to the emitter of Q526, the disconnect amplifier, turning it off. The sweep is then enabled to run up.

Now let's take a look at another condition. There is no sweep and the beam is at the right side of the screen.

Check TP534. It should be at ≈13 V. Check to see that Q408, Q406 and CR406 are on. This should flip the Reset Multi, turning Q432 on and Q436 off. TP436 should be at −3.5 V to stop the triggers and end the sweep.

This procedure should enable you to speedily troubleshoot the sweep generator circuits in the 7B70, 7B71, 7B50 and 7B51 time bases. In future issues of Tekscope we will discuss troubleshooting techniques for other types of time bases used in Tektronix instruments.



Block diagram of 7B71 sweep generator.

INSTRUMENTS FOR SALE

C12 camera, F1.9, 0.9 mag., $325 or best offer. Mr. Jorgensen, 234 Henley, Glenview, IL 60025 (312) 722-6370.

C27 camera w/pack-film back, F1.9, 0.85 mag. lens and case. $300. Jim W. Jenkins, 300 Warehouse Ave., Anchorage, Alaska 99501, (907) 279-2232.

C-27/530 Bezel, Hood & Access, $375 or best offer. 500/53 Scopemobile $60. Robert Sonner, Bull & Roberts, 785 Central Ave. Maryhill, NJ 07974, (201) 464-6500.

C30A w/pack film back, access., case. Mr. Leonard Forrest, (516) 623-4108.

S54, Make offer, Mr. Carl Burns, (213) 848-9632.

S54 w/X10 & X1 probes. $175. John Perkovich, Rt. 1, Cascade, Wisconsin 53011. (414) 528-8622.

TLD83, $1150, Mr. Chenauski, Radio Shop, Inc., Worcester Municipal Airport, Worcester, Mass 01602, (617) 757-6954.

1L40, 1.5 to 40 GHZ, $1775 or offer. William A. Gentry, Pres., Microwave Engineering, 750 Davis Ave., Pittsburg, CA 94567, (415) 439-2141.

7L12, J. Parker Electronics, 33 Mill St., Hornell, NY 14843, (607) 871-6110 (Days) or (607) 324-7235 (After 5 p.m.).

11B2 for 647A, make offer or trade for 10A1, Jeff Cook, Sound Storms, 19 Ocean View, Santa Barbara, CA (805) 962-1080.

105, $125; 107, $90; 180A, $250; 190A, $175. All calibrated, Call (213) 341-4700.

130, $150, C. E. Spitz, Box 4095, Arlington, VA 22204.

147 Generator, $2100, Frank Grab (203) 227-1324, 20 Gray's Farm Road, Westport, Conn. 06880.

161 & (2) 163's. Need 162. L. E. Herzmark, Biomedical Inst. Systems, 8205 Briar, Prairie Village, Kansas 66208, (913) 649-7592.

211, R. C. Wagner, 830 Sevely Drive, Mt. View, CA 94041 (415) 967-2776.

230, 568, 3S1, 3T6, Joe Andrada, Sprague Electric, P.O. Box 1509, Visalia, CA 93277. (209) 732-4585.

310A, $350 or best offer; 545/53/54C/K, $600 w/access. or best offer. (401) 596-5740 (8:30 - 5:00)

317, $300; 545 w/cart, $500; (2) CA, $50 ea; M, $85; 575 w/cart, $700; 543 w/cart, $200, Mr. Crockett, Discon, 1322 N.W. 14 Ave., Pampano Beach, FL 33060 (305) 974-0773.

317, $275, M. H. Gonsior (714) 871-3232, Ext. 3367.

321, w/Nicad battery & case; D54 with probes; D. E. Cummins, 3618 Pine Ridge Road, Orlando, FL 32808 (305) 295-5120

(2) 321A, new; (1) 506/9A1/3B1, (2) 531 w/ (2) 53/54's, Al Early c/o Sperry Univac, World Wide Distribution Center, Elk Grove Village, IL 60007, (312) 593-1600.

INSTRUMENTS FOR SALE

323, $700; 323/1401A, $2350; 453, $1250; RM564B, 3B3, 3A72, $1975, Ivan Sundstrom, 695 E. 43rd. Eugene, OR 97405 (503) 686-2380. Evenings and weekends.

432, Emery Knight, Executive Systems, Inc., 2550 W. Oakland Park Blvd., Ft. Lauderdale, FL 33313 (305) 739-2000.

454A, $2000, Arnold Bishop, P.O. Box 224, Solvay, NY 13209, (315) 488-4616.

465, make offer, Eves, (215) 543-8098.

503, $500; 503A, $650; (2) 504's, $395 ea; 515, $450. Gene McCain, John Fluke Mfg. Co., P.O. Box 7428, Seattle, Washington 98133, (206) 774-2333.

517A, $275. Mr. James Wotton, 535 Carlton Road, Westfield, NJ 07090 (201) 232-1771.

519, $2500; 551, power supply/without plug-ins, $1250; 105, 180A & 161, $200 ea; Allscot Equipment Co., Scotland, Conn. 06264, Mr. Roger L. Kitfield; (203) 774-5700.

(3) 531A w/plug-ins and carts, $550 ea., Barry Perske, Tally Corp., 8301 South 180th, Kent, WA 98031; (206) 251-5500.

532 with cart & access., Wayne Burkhardt, RFD #2, Spencer, Mass. 01562, (617) 765-9711, Ext. 2318.

535, $325, W. K. Cordes, 6721 Sylvan, Houston, TX 77023, (713) 926-3217.

535A with CA plug-in unit, Best offer, Mr. Merle Smith, 9350 E. Flair Drive, El Monte, CA 91734, (213) 572-5188.

541, w/53/54k, 1A1, 2-P6023, 1-P6028. $750, Mr. Reichenberg, Xytek Corp., 3850 Frontier Ave., Boulder, CO 80301, (303) 447-2531, (303) 494-0651 home phone.

545A/1A1, $900. Mr. Carl Hagerling, 2273 Grandview Ave., Apt 3, Cleveland, OH 44106, (216) 229-2947.

547, 1A1, 202-2B ($1800); 1L10, 132, $830. Mr. Richard Blanchard (213) 786-1214.

Spectrum Ana. plug-in for 540 Series, Model 3742, 3.7 - 4.6 GHz. highest offer; 535 w/ plug-ins & probes, highest offer, Lightner Labs, 1980 N. Atlantic Ave., Suite 109, Cocoa Beach, FL 32931.

547, 1A1, 202, 1S2, or 1S2 only. R. N. Grubb, 7762 Brockway Dr., Boulder, CO 80302.

549, w/1S1, 1A7 and Z, $950; (1) 453, $800; 184 and 106, $100 ea., W. Mioduszewski, 206 Scoles Ave., Clifton, NJ 07012; (201) 472-3284.

555, $1,200; Q plug-in $100, D plug-in $40., St. Clair Consultants, 23415 Ryan, Warren, MI 48091, (313) 756-5320, Contact Carl Lizut.

561, 2B67, 3A6 or 3A1, $700 or $600. Daniel, (213) 792-4962 eves.

6R1; 575, $800. Transatek, Inc., P.O. Box 25984, Albuquerque, NM 87125 (505) 243-2156.

575, $650. Thomas Organ Company, Mr. Chet Mazgay, (213) 892-3131.

575, $800, or best offer., F. Louthan, Phipps & Bird, Inc., P.O. Box 2V, Richmond, VA 23205 (804) 644-5401.

INSTRUMENTS FOR SALE

581/81/82, $725; 531, $425; 555/21/22, $775; plug-ins available for single channel $50-60; CA's $135. W. A. Shirer, 9350 Carmichael Drive, La Mesa, CA 92041, (714) 466-3578.

661 w/5T1A and 4S2, $850 or best offer or trade for Tek 540 series, Electroway Co., 1S. 624 Lambert Road, Glen Ellyn, IL 60137 (Call Rex Farrell, (312) 469-9511.

661/4S1 dual trace/5T1A, to trade for 15 plus MHZ real time scope, L. M. Spokas, 12 Essex St., Deep River, Conn 06417 (203) 526-2159.

5103/D10, -5A22N, 5CT1N, 5B10N; 3 months old, $1295, Audio-Tronics, Mr. John R. Sandridge, 6701 Beach Boulevard, P.O. Box 7187, Jacksonville, FL 32216. Bsns: (904) 724-7335; Home: (904) 786-4839.

5103N/D10, $500, H. Howard, Ryder Magnetics Sales Corp., (213) 469-6391.

7503, 7A18, 7D13, 7B53A, Communication Arts, 1101 Pearl St., Boulder, CO 80302 (303) 447-8202.

7504, 7A16, 7A15, 7B50, 7B51, best offer, Audrey Jackson, Epps Air Service, Dekalb - Peachtree Airport, Chamblee, GA 30341, (404) 458-9851.

(2) P6042; (1) CT5, Mr. Dick Dixon, Electro Module, Pomona, CA 91767, (714) 593-3565.

Type B plug-in, $45; 53/54C, $85. Dennis Kraft, (213) 889-2211, X2854.

INSTRUMENTS WANTED

2A63, Frank E. Burris, 898 Rhodes Hall, Location #30, Univ. of Cincinnati, Cincinnati, OH 45221, (513) 475-3227 or 475-4461.

3A72. Sandy Fuller, Viscount Productions, 650 Miami Circle, Atlanta, Georgia, 30324, (404) 261-6240.

3B3, Ken Chaney, 4600 E. Broadway St., Long Beach, CA 90803. (213) 433-3824.

3B3 or 2B67 to buy or trade for 53G, T, N, or 53/54C. J. L. Kavanau, UCLA, Dept. of Biology, Los Angeles, CA 90024. (213) 825-3474 (9 a.m.-6 p.m.)

162, L. E. Herzmark, Biomedical Instrument Systems, 8205 Briar, Prairie Village, Kansas 66208 (913) 649-7592.

422, 453, or D66, Abald Krell, 387 Eastern Parkway, Brooklyn, NY 11216, (212) 467-2966.

556, Dr. Sepucha, Aerodyne Research, Inc., Burlington, MA 01803 (Northwest Industrial Park) (617) 272-1100.

575, Jim Kavitz, Washington Electronics Service, P.O. Box 345, Abingdon, VA 24210, (703) 628-2477.

576 or 577; Steve Aivazian, Semi-conductor Tech. Inc., 124-14 22 Avenue, College Point, NY 11356 (212) 445-4466.

15MHz or better, dual trace, 10 mv vertical sens or better, delayed sweep. Bill Hoyt, 555 Middlefield, Mt. View, CA 94040, (415) 961-5152.

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